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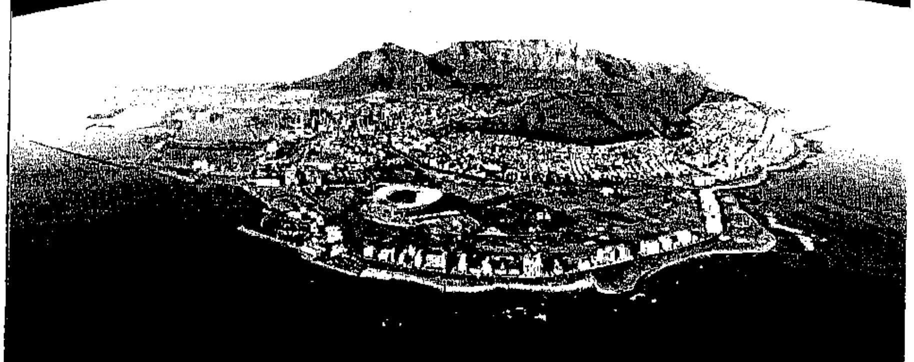

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Economic Feasibility Of Clean Coal Technologies

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Abstract

Recent developments in the energy sector prove that we are witnessing a shift in the place of commodities within global economy. Coal as a source of heat and power has kept and is meant to keep its hegemony in Europe and the USA; this along with recent encouraged fight against global warming and the factual lower yield of coal technologies claims for the review of these and the development of less pollutant processes per unit of useful energy, so-called Clean Coal Technologies.

This document provides an assessment of the technical aspects of these technologies. More specifically it focuses on the economical evaluation of carbon separation and capture on Integrated Gasification Combined Cycles using recent cost estimates and power market values from a major European power market.

According to these calculations, European emissions' allowances price and allocation policy will play a relevant role in the future of these technologies. Under the hypothesis of 0% free allowances, IGCC with carbon capture could prove more economical than a greenfield conventional pulverized coal starting from slightly above 30€/t CO_2. Further operational flexibility from new designs is as well discussed.

Introduction

Coal supplies about 40% of the world's electricity and is also essential to the production of more than 2/3 of world's steel production; as such, coal as a source of heat and power has kept and is meant to keep its hegemony in the USA and Europe, where more than 50% of the installed power capacity is coal-based. Coal amounts to the largest share of available reserves and resources worldwide that could provide energy for more than 100 years at current prices and over 1000 years based on current resources

This dependency and/or convenience of coal technologies along with the recent encouraged fight against global warming and their factual lower yield claims for a review of these processes and the development of improved and more efficient designs per unit of useful energy that are commonly referred to as clean coal technologies.

Indeed, there is a growing concern regarding the future role of coal in power generation and how carbon policies will encourage Research & Development in advanced coal technologies. According to the EU Commission in Europe about 161 GW of new coal and lignite power plants is projected to be commissioned between 2006 and 2030, where two third of these refers to advanced coal technologies, mostly supercritical combustion technologies.

Provided that carbon dioxide accounts for 72% of GHG from anthropomorphic source, along with the pioneer creation in Europe of a carbon market, much focus is set on carbon dioxide capture and storage technologies because of their theoretically more intensive research incentive due to real carbon emission cost.

Clean coal technologies encompass a wide range of techniques meant to enhance the coal's life cycle acceptability from the environmental point of view. These can be categorized by their position within the combustion process of the fuel into:

- Pre-combustion
  - Includes raw material preparation to minimize the presence of unwanted impurities such as ashes, sulfur, chlorine, arsenic, phosphorus and moisture. A considerable number of research papers focus on the elimination of mercury, since although its concentration is indeed low, considering the big volumes in place, volatile mercury leads to a toxicity problem. Pre-combustion capture can be achieved through brand-new designs such as coal gasification reactors.

- Combustion
  - Co-combustion, provides further fuel flexibility to the plant at the same time as higher conversion yield and lower CO_2, NOx and SO_2 emissions than conventional 100% pulverized coal technologies, because the lower specific content of S and N in the fuel blend.

    Two promising technologies are described in this document: Oxy-combustion and Chemical-Looping. The former refers to the process of coal combustion in an oxygen-rich atmosphere whereas chemical-looping involves the indirect combustion of coal via a solid oxygen-carrier continuously looping between the coal reactor and an air-fired boiler.
- Post-combustion
  - Includes CO_2, SO_2, NOx, ashes and mercury elimination principally. Gases elimination is normally performed with a counter-flow shower of the boiler flue gases with solvents that are at a latter stage regenerated extracting the impurities from the solvent in order to operate in closed circuit due to their high cost.

Economical Assessment

Carbon Capture and Storage will be presented in this work along with latest research published on the issue since the development of technologies allowing containing, capturing and storing the hazardous flue products from coal combustion is likely to remain the industry's largest challenge, both from the scientific and communication points of view.

As of today carbon capture technologies are regarded as one of the most realistic options for meaningful GHG emissions reduction since carbon dioxide capture is possible not only from power stations but also from chemical, steel or cement industries; then it can be stored in geological formations such as saline aquifers or expired oil and gas reservoirs.

However, due to the additional costs associated with these technologies, companies will generally require some financial incentives to make projects economically viable. For this reason in the European Union we have developed the worlds' first carbon market, born to provide transparency and liquidity to the exchange of emission certificates foreseeing the future shortfall of allowances as the engagements derived from Kyoto become more and more restrictive.

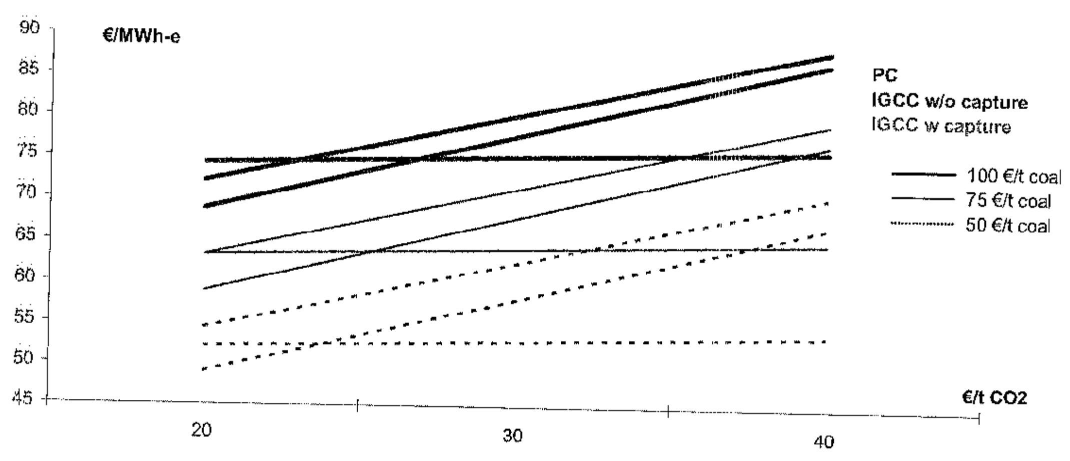
According to recent market data presented in this paper, through simple calculations and always focusing on the European market, it is intended to provide a rough estimation of the energy and emissions' allocation policies as well as pure market-driven conditions that enhance the economical feasibility of these carbon capture technologies.

The analysis presented in the document is based on costs, yields and correlations recently available on research documents and own hypothesis subject to sensitivity analysis. Plant life used in the calculations intends to account for the higher risk involved in the construction and operation of these new designs. Under the Base Case, the following parameters will be used:

Technology	Yield	Specific Carbon	Relative OpEx	Relative CapEx	Plant Life
PC	36%	0.90	-	-	30yrs
IGCC w/o capture	40%	0.81	95%	125%	15yrs
IGCC w capture	32%	0.09	124%	175%	15yrs

At breakeven, the marginal additional cost of a given technology per MWh-electric generated should balance the carbon cost saved per MWh-electric generated. If we assume equal plant availability and 100% carbon market exposure, the former is a function of additional capital costs and operational expenses as well as overall yield of the plant, whereas the latter is a function of the conversion yield and market carbon cost.

Transport and storage costs have been disregarded from the analysis and calculations because transport costs estimations for a reasonable range are small enough to be immediately offset by carbon price volatility. Additionally, storage costs are, under certain scenarios, negligible since when pumped into oil reservoirs the oil enhancing recuperation is likely to pay for the injection and storage cost.
The total power generation cost in current euros per MWh-electric for the three above-mentioned technologies with two degrees of freedom: carbon cost and fuel cost is presented in the figure below under the hypothesis of 100% carbon market exposure:



As results from the chart, IGCC with carbon capture could prove more economical than a greenfield conventional pulverized coal starting from 30€/t CO_2. This document also addresses further opportunities for these new technologies such as their inherent operational flexibility with translates in potential value. Providing the elasticity of a gas-fired combined cycle to a raw solid coal-fired plant can boost the economical feasibility of these investments because the market prices this additional operational elasticity. This along with the pricing differential per energy unit between both fuels represents a great deal of profitability to be exploited.

In the economical discussion, it has been compared advanced against conventional technologies, but in a broader sense, economical feasibility starts from the moment that the cost per MWh-electric produced is lower than its market selling price. This difference means that a number of companies would be ready to invest into clean coal technologies even though they might end up being slightly more expensive than conventional ones, yielding lower economic returns, but still producing profits at the same time that they strategically position themselves on the R&D race and generates a positive marketing image and branding, specially now.

For advanced coal technologies themselves learning curve and R&D will probably result in lower relative capital and operating costs, putting further pressure on polluting technologies provided the implementation of a favorable policy framework.

More efficient technologies such as chemical-looping and oxy-combustion are likely to enlarge the set of commercial scale options beyond ultra-critical coal plants in the near future as we can already derive from the large amount of research projects devoted to these and the economical commitment from companies, governments and supra-national organizations.

Although the creation of the market does not motivate for emissions' reduction unless the system is short of quotas overall we have succeeded to create social concern and awareness on the fact that there is a premium to pay on pollutant not environmentally-friendly technologies. Next logical step would be the reduction of quotas below the economic growth rate to account for better energy efficiency and in order to incentive corporate research on "cleaner" technologies.

Conclusions

With the ratification of Kyoto protocol followed by the creation of a carbon market in Europe we are putting in place the tools to significantly reduce GHG emissions. Although the creation of the market does not motivate for emissions' reduction unless the system is short of quotas overall we have succeeded to create social concern and awareness on the fact that there is a premium to pay on pollutant not environmentally-friendly technologies.

This has been a great success from the recent experience where the sentiment was that the premium belonged to "sustainable development"; that being "green" costs more. Nowadays we widely accept the idea that not being "green" must represent the most expensive option...

Next logical step would be the reduction of quotas below the economic growth rate to account for better energy efficiency and in order to incentive corporate research on "cleaner" technologies. As mentioned before in this document, there is certain controversy to the term "Clean Coal Technologies". From my point of view, we can say "clean" when we mean to cleaner and "cleaner" means less specific pollution per useful energy quantity.

In that respect higher yield and capture technologies are definitely cleaner than conventional pulverized coal which represents the logical benchmark. Still, some arguments exists against this rationale and some researchers argue that considering the total life cycle of carbon when using most these technologies offset the evident gains on the exhaust stack of the plant.

Clean Coal Technologies mark the way for future efficient use of the most abundant fossil fuel. Although falling out of the scope of this document, it deserves special attention the next developments in ultra-critic coal plants, Combined Power and Heat" technologies (CPH), and those processes dedicated to the hydro-gasification of coal that result in a flue gas rich in methane, likely to be followed by highly efficient and flexible combined cycle designs at the time that provide a partial hedge of fuel cost against oil prices.

According to the study from the MIT dated 2007 and titled "The Future of Coal", in China, the equivalent to two 500MW coal-fired plants are built every week. The document follows highlighting that in the USA about 1.5 billion tons of carbon dioxide are produced every year from coal-fired power plants and if all this carbon should be captured and transported it would amount to three times the weight of current natural gas flowing through the country.

From the presentation of the wide variety of technologies, we can understand the scientific effort and level of investment involved. Regarding the particular case of Spain, a large number of research papers and projects are lead by Spanish researchers. It is worth highlighting the examples in biomass co-combustion providing further value to wastes such as plastic waste, vine shoots, olive wastes or almond residues.

Focusing on coal research, Spain has significantly contributed to research in the chemical –looping ENCAP CO2 European program focusing on oxygen carriers and relevant contribution to research on CO_2 capture solvents and mercury capture.

At current conditions, IGCC with carbon capture represents an economically feasible technology from 30€ per ton of carbon dioxide under the hypothesis of 100% market exposure to emissions' certificates. The reason to disregard transport and storage costs in the calculations is due to the fact that the transport costs are small enough to be immediately offset by carbon price volatility.

Additionally, storage costs are, under certain scenarios, negligible since when pumped into oil reservoirs the oil enhancing recuperation is likely to pay for the injection and storage cost. Furthermore, these two stages are still in very premature phase of development and learning curve as well as favorable policies, as well as new ideas will come through.

For advanced coal technologies themselves learning curve and R&D will probably result in lower relative capital and operating costs, putting further pressure on polluting technologies provided the implementation of a favorable policy framework.

More efficient technologies such as chemical-looping and oxy-combustion are likely to enlarge the set of commercial scale options beyond ultra-critical coal plants in the near future as we can already derive from the large amount of research projects devoted to these and the economical commitment from companies, governments and supra-national organizations.

One more opportunity for Advanced Coal Technologies that has been tried to highlight in this document is the value attached to the brand-new flexibility of some designs, providing the elasticity of a gas-fired combined cycle to a raw solid coal-fired plant. This along with the pricing differential per energy unit between both fuels represents a great deal of profitability to be exploited.

Discussing about GHG's issue and the big numbers involved, policy makers recognize the high share of carbon emissions related to processes where carbon is expelled to the atmosphere hot and representing a waste and processes whose objective is to obtain heat. Combining these two into one only integrated process would prove potentially feasible for the heat "producers" (valuing heat from its waste form into a marketable byproduct) and useful to heat "demanders" by enlarging the range of heat sources, enhancing competition thus providing heat's price efficiency and further security of supply.

If we have learned until now that there is cost associated to carbon emissions (hence opportunity cost or value), we will someday recognize the value behind heat as flue or waste. Once the sustainable development machine will increase its speed, it is likely that there will be costs associated to heat expelled to the atmosphere.

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